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Conformable Tanks for Natural Gas Storage

Abstract

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Limited vehicle range remains a primary obstacle to the widespread public acceptance of natural gas vehicles. For on-board storage of compressed natural gas (CNG), current practice relies on one or more cylindrical tanks designed to a service pressure of 3,000 - 3,600 psi. While cylinders represent efficient structures for containing the required pressure, they often do not package well within the volume envelope available on the vehicle for fuel storage. This results in either unacceptable range, the use of multiple cylinders reducing the cargo capacity of the vehicle, or both.

Under contract with Brookhaven National Laboratory, Thiokol is addressing the problem of maximizing onboard CNG storage through the development of a conformable tank concept. Consisting of a multi-celled structure composed of adjoining cylindrical segments, this approach can increase storage capacity within a rectangular envelope by up to 50% compared to multiple cylinders. By altering the number of cells, the tank can be tailored to conform to the available envelope. The basic conformable concept has previously been demonstrated at Thiokol for low-pressure propane storage using welded aluminum construction; the propane tank is currently in production for Chrysler Canada, Ltd. The challenge of the current program is to extend the technology to the high pressure requirements of CNG storage.

Based on initial material and process trade studies considering pressure requirements as well as cost and weight goals, a carbon/epoxy filament wound construction was down-selected for development. Design activities focused on modifying the basic design to take advantage of the directional strength of the carbon fibers while minimizing the effect of their low cross-ply strength. To demonstrate the structural capabilities of the resulting composite conformable tank design and fabrication process, a subscale, two-cell prototype design was developed. The prototype has a volume capacity of 7.5 gallons--50% more than the capacity of a cylinder within the same envelope.

The target burst pressure for the prototype tank was 8,100 psi, corresponding to a safety factor of 2.25 for a 3,600 psi service pressure tank; this is consistent with current qualification requirements for CNG fuel tanks. After several design iterations, hydroburst testing of the prototype resulted in a burst pressure of 8,820 psi, demonstrating that the composite conformable tank concept can meet the strength requirements for a CNG fuel tank.

Current efforts are directed toward the design and fabrication of a three-cell prototype to demonstrate the tailorability of the concept to the available vehicle storage envelope. The first three-cell tank to be tested exhibited a burst pressure of 7,270 psi, or 90% of the requirement; design iterations and optimization are ongoing to increase the burst pressure to the 8,100 psi target. Future direction will encompass development and testing of an impermeable tank liner and further qualification testing to the expected service environment.